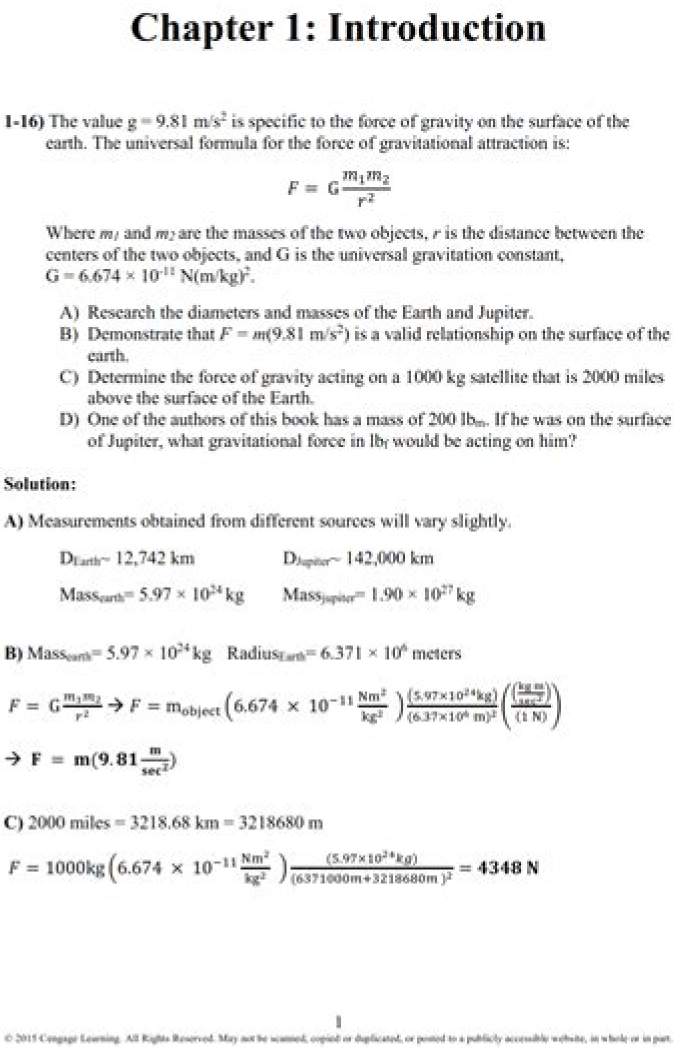
Fundamentals Of Thermodynamics Solution Chapter 4



Chapter 1: Introduction

1-16) The value g = 9.81 m/s² is specific to the force of gravity on the surface of the earth. The universal formula for the force of gravitational attraction is:

$$F = G\frac{m_1 m_2}{r^2}$$

Where m_1 and m_2 are the masses of the two objects, r is the distance between the centers of the two objects, and G is the universal gravitation constant, G = 6.674 × 10^{-11} N(m/kg)².

A) Research the diameters and masses of the Earth and Jupiter.
B) Demonstrate that $F = m(9.81 \text{ m/s}^2)$ is a valid relationship on the surface of the earth.
C) Determine the force of gravity acting on a 1000 kg satellite that is 2000 miles above the surface of the Earth.
D) One of the authors of this book has a mass of 200 lb_m. If he was on the surface of Jupiter, what gravitational force in lb_f would be acting on him?

Solution:

A) Measurements obtained from different sources will vary slightly.

D_{Earth}~ 12,742 km $D_{Jupiter}$~ 142,000 km

$Mass_{earth}$= 5.97 × 10^{24} kg $Mass_{jupiter}$= 1.90 × 10^{27} kg

B) $Mass_{earth}$= 5.97 × 10^{24} kg $Radius_{Earth}$= 6.371 × 10^{6} meters

$$F = G\frac{m_1 m_2}{r^2} \rightarrow F = m_{object}\left(6.674 \times 10^{-11}\frac{Nm^2}{kg^2}\right)\frac{(5.97\times10^{24}kg)}{(6.37\times10^{6}\ m)^2}\left(\frac{\left(\frac{kg\ m}{sec^2}\right)}{(1\ N)}\right)$$

$$\rightarrow \mathbf{F = m(9.81\frac{m}{sec^2})}$$

C) 2000 miles = 3218.68 km = 3218680 m

$$F = 1000kg\left(6.674 \times 10^{-11}\frac{Nm^2}{kg^2}\right)\frac{(5.97\times10^{24}kg)}{(6371000m+3218680m)^2} = \mathbf{4348\ N}$$

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Fundamentals of thermodynamics solution chapter 4 delves into the critical concepts and principles that govern the behavior of thermal systems. This chapter typically focuses on the first and second laws of thermodynamics, heat transfer, and the properties of substances. Understanding these principles is essential for engineering applications and scientific research involving energy exchanges. In this article, we will explore the key topics covered in Chapter 4, emphasizing the fundamental concepts that are vital for mastering thermodynamics.

1. Overview of Thermodynamics

Thermodynamics is a branch of physics that deals with the relationships between heat, work, temperature, and energy. It lays the groundwork for understanding how energy is transferred and transformed in physical systems. In Chapter 4, we focus on several core principles that form the foundation of thermodynamic analysis.

1.1 Key Terms and Definitions

Before diving into specific laws and applications, it's essential to clarify some key terms:

- System: A defined quantity of matter or region in space chosen for analysis.
- Surroundings: Everything outside the system that can interact with it.
- Boundary: The surface that separates the system from its surroundings.
- State: The condition of a system described by its properties (e.g., pressure, temperature, volume).
- Process: A transformation that occurs when a system changes from one state to another.

1.2 Types of Systems

Systems can be categorized based on their ability to exchange energy and matter with their surroundings:

- Isolated System: No exchange of energy or matter with the surroundings.
- Closed System: Energy can be exchanged, but matter cannot.
- Open System: Both energy and matter can be exchanged.

Understanding these classifications is crucial for analyzing thermodynamic processes.

2. The First Law of Thermodynamics

The first law of thermodynamics is a statement of the conservation of energy, asserting that energy cannot be created or destroyed, only transformed from one form to another. Mathematically, it is expressed as:

$$
\Delta U = Q - W
$$

Where:
- ΔU = Change in internal energy of the system
- Q = Heat added to the system
- W = Work done by the system

2.1 Internal Energy

Internal energy is the total energy contained within a system due to the kinetic and potential energies of its molecules. Changes in internal energy can result from heat transfer or work performed on or by the system. Understanding internal energy is crucial for predicting how systems respond to various heat and work interactions.

2.2 Heat Transfer

Heat transfer can occur through three primary mechanisms:

- Conduction: Transfer of heat through a solid material due to temperature differences. Governed by Fourier's law.
- Convection: Transfer of heat between a solid surface and a fluid in motion. Involves both conduction and the bulk movement of fluid.
- Radiation: Transfer of energy through electromagnetic waves without the need for a medium.

Each mechanism plays a significant role in thermodynamic processes and applications.

2.3 Work Done in Thermodynamic Processes

Work can be done on or by the system during a process. Common types of work include:

- Boundary Work: Occurs when the volume of a system changes against an external pressure.
- Shaft Work: Associated with rotating machinery, such as turbines and compressors.
- Electrical Work: Involves energy transfer through electric currents.

Understanding these forms of work is critical for analyzing energy transformations in thermodynamic systems.

3. The Second Law of Thermodynamics

The second law of thermodynamics introduces the concept of entropy, a measure of the disorder or randomness in a system. It states that in any energy transfer or transformation, the total entropy of an isolated system can never decrease. This leads to the notion that energy conversions are not 100% efficient.

3.1 Entropy and Its Significance

Entropy is a central concept in thermodynamics with several critical implications:

- Direction of Processes: Natural processes tend to move towards a state of higher entropy.
- Efficiency of Engines: Real engines cannot convert heat energy into work with 100% efficiency due to the increase in entropy.
- Spontaneity: A process is spontaneous if it leads to an overall increase in entropy.

Understanding entropy is essential for analyzing the feasibility and efficiency of thermodynamic processes.

3.2 Reversible and Irreversible Processes

Processes can be classified as reversible or irreversible based on their ability to return to their original state:

- Reversible Process: An idealized process that can be reversed without leaving any change in either the system or surroundings. These processes are characterized by equilibrium and maximum efficiency.
- Irreversible Process: Real processes that cannot be reversed due to friction, turbulence, or other dissipative effects. These processes result in an increase in entropy.

Recognizing the differences between these two types of processes is vital for designing and analyzing thermodynamic cycles.

4. Thermodynamic Cycles

Thermodynamic cycles are sequences of processes that return a system to its initial state. They are commonly used in engines and refrigerators. Chapter 4 often covers several fundamental cycles, including:

4.1 Carnot Cycle

The Carnot cycle is an idealized thermodynamic cycle consisting of two isothermal processes and two adiabatic processes. It serves as a benchmark for the efficiency of real engines.

- Isothermal Expansion: The system absorbs heat from a high-temperature reservoir.
- Adiabatic Expansion: The system expands without heat exchange, doing work on the surroundings.
- Isothermal Compression: The system releases heat to a low-temperature reservoir.
- Adiabatic Compression: The system is compressed without heat exchange.

The efficiency of a Carnot engine is given by:

$$
\eta = 1 - \frac{T_C}{T_H}
$$

Where T_C and T_H are the absolute temperatures of the cold and hot reservoirs, respectively.

4.2 Rankine Cycle

The Rankine cycle is commonly used in steam power plants. It consists of four stages:

1. Heating: Water is heated at constant pressure to produce steam.
2. Expansion: The steam expands through a turbine, doing work.
3. Condensation: The steam is condensed back into water at constant pressure.
4. Pumping: The water is pumped back to the boiler pressure.

The Rankine cycle's efficiency can be enhanced by superheating the steam and using regenerative heat exchangers.

4.3 Refrigeration Cycle

The refrigeration cycle is the opposite of the heat engine cycle, transferring heat from a cold reservoir to a hot reservoir. Its components include:

- Evaporator: Absorbs heat from the refrigerated space.
- Compressor: Increases the pressure and temperature of the refrigerant.
- Condenser: Releases heat to the surroundings.
- Expansion Valve: Reduces the pressure of the refrigerant before it enters the evaporator.

Understanding refrigeration cycles is essential for applications in HVAC and food preservation.

5. Conclusion

The fundamentals of thermodynamics solution chapter 4 encapsulates essential principles governing energy transfer and transformations within systems. By grasping the first and second laws of thermodynamics, internal energy, heat transfer processes, and the significance of entropy, one can effectively analyze and design various thermal systems. Understanding thermodynamic cycles like the Carnot, Rankine, and refrigeration cycles is crucial for engineers and scientists in optimizing energy use and developing efficient machines. Overall, mastering these concepts is a stepping stone towards advanced studies and practical applications in thermodynamics.

Frequently Asked Questions

What is the main focus of Chapter 4 in the Fundamentals of Thermodynamics?

Chapter 4 primarily focuses on the laws of thermodynamics, particularly the first and second laws, and their applications in various thermodynamic processes.

How does the first law of thermodynamics apply to closed systems?

The first law of thermodynamics states that energy cannot be created or destroyed, only transformed. In closed systems, any change in internal energy is equal to the heat added to the system minus the work done by the system.

What is an example of a thermodynamic process discussed in Chapter 4?

An example of a thermodynamic process discussed in Chapter 4 is the isothermal process, where the temperature remains constant while heat is exchanged with the surroundings.

Can you explain the concept of work in thermodynamics as per Chapter 4?

In thermodynamics, work is defined as the energy transfer that occurs when a force is applied over a distance. Chapter 4 details how work can be calculated in various processes, such as moving a piston in a cylinder.

What role do state functions play in thermodynamics according to Chapter 4?

State functions, such as internal energy, enthalpy, and entropy, are properties that depend only on the state of the system, not on how it reached that state. Chapter 4 emphasizes their importance in analyzing thermodynamic processes.

How does Chapter 4 describe the concept of heat transfer?

Chapter 4 describes heat transfer as the energy transfer due to a temperature difference between systems or surroundings, and it can occur via conduction, convection, or radiation.

What is the significance of the Carnot cycle in thermodynamics?

The Carnot cycle is significant because it represents an idealized thermodynamic cycle that provides the maximum possible efficiency for a heat engine operating between two temperature reservoirs.

What are some common misconceptions about the second law of thermodynamics mentioned in Chapter 4?

Common misconceptions include the belief that heat naturally flows from cold to hot and that all processes are reversible. Chapter 4 clarifies that the second law indicates the direction of spontaneous processes and the concept of entropy.

What equations are derived in Chapter 4 for calculating work done in thermodynamic systems?

Chapter 4 derives several equations, including $W = P\Delta V$ for isobaric processes and $W = \int PdV$ for general processes, where W is work, P is pressure, and ΔV is the change in volume.

How does Chapter 4 relate thermodynamics to real-world applications?

Chapter 4 illustrates how thermodynamic principles are applied in various fields, including engines, refrigeration, and environmental science, by demonstrating real-world examples and problem-solving techniques.

Fundamentals Of Thermodynamics Solution Chapter 4

FUNDAMENTAL Definition & Meaning - Merriam-Webster
essential, fundamental, vital, cardinal mean so important as to be indispensable. essential implies belonging to the very nature of a thing and therefore being incapable of removal without destroying the thing itself or its character.

FUNDAMENTALS | English meaning - Cambridge Dictionary
The fundamentals include modularity, anticipation of change, generality and an incremental approach.

FUNDAMENTAL definition and meaning | Collins English …
a basic principle, rule, law, or the like, that serves as the groundwork of a system; essential part to master the fundamentals of a trade

Fundamentals - definition of fundamentals by The Free Dictionary
Bedrock is literally a hard, solid layer of rock underlying the upper strata of soil or other rock. Thus, by extension, it is any foundation or basis. Used literally as early as 1850 in Nelson Kingsley’s Diary, the phrase appeared in its figurative sense by …

fundamentals - WordReference.com Dictionary of English
a principle, law, etc, that serves as the basis of an idea or system: teaching small children the fundamentals of road safety the principal or lowest note of a harmonic series

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noun a basic principle, rule, law, or the like, that serves as the groundwork of a system; essential part. to master the fundamentals of a trade.

Essentials vs. Fundamentals - What's the Difference? | This vs. That
Fundamentals, on the other hand, encompass the foundational concepts and skills that form the basis for more advanced learning and application. While Essentials focus on the key elements needed for success, Fundamentals delve deeper into the core principles that underpin a subject.

Fundamental - Definition, Meaning & Synonyms
When asked what the fundamental, or essential, principles of life are, a teenager might reply, "Breathe. Be a good friend. Eat chocolate. Get gas money." Fundamental has its roots in the Latin word fundamentum, which means "foundation."

fundamental - Wiktionary, the free dictionary
Jun 20, 2025 · fundamental (plural fundamentals) (generic, singular) A basic truth, elementary concept, principle, rule, or law. An individual fundamental will often serve as a building block used to form a complex idea.

FUNDAMENTALS | meaning - Cambridge Learner's Dictionary
FUNDAMENTALS definition: the main principles, or most important parts of something: . Learn more.

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